Survey of Red Sea Urchin Populations In The Dundas Group, British Columbia, 2003

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SURVEY OF RED SEA URCHIN POPULATIONS IN THE DUNDAS GROUP, BRITISH COLUMBIA, 2003

by

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ABSTRACT

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in the Dundas Group, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2751: iii + 27 p.

A survey of red sea urchin populations was conducted in the Dundas Group (Pacific Fisheries Management sub-areas 3-1, 3-2, 4-1 and 4-5) during August/ September, 2003. A total of 67 transects were surveyed by SCUBA divers, and 2460 red sea urchins were measured. The total mean density of red sea urchins of all sizes was 1.32/m^2 and for legal-sized red sea urchins (≥90 mm test diameter, TD) the density was 0.97/m^2. There was no significant difference in estimated mean density (number/m^2) or biomass (g/m^2) for red sea urchins found inside (30 transects) and outside (37 transects) previously fished commercial bed areas. Overall, 5.6% of all red urchins measured were ≤50 mm TD whereas 73.3% were of legal size for the commercial fishery.

RÉSUMÉ

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in the Dundas Group, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2751: iii + 27 p.

Un relevé des populations d'oursins rouges a été réalisé en août-septembre 2003 dans l'archipel Dundas (sous-secteurs 3-1, 3-2, 4-1 et 4-5 de gestion des pêches du Pacifique). Au total, 67 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 2460 oursins rouges. La densité moyenne totale des oursins rouges de toutes tailles était de 1,32/m^2 et, pour les oursins de taille réglementaire (≥90 mm de diamètre du test, DT), la densité était de 0,97/m^2. On n'a pas noté de différences significatives dans la densité moyenne estimée (nombre/m^2) ni dans la biomasse (g/m^2) entre les oursins rouges observés à l'intérieur (30 transects) et à l'extérieur (37 transects) de gisements auparavant exploités par la pêche commerciale. Dans l'ensemble, 5,6 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 73,3 % avaient la taille réglementaire pour la pêche commerciale.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution along the Pacific Coast of North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). Red sea urchins are found throughout shallow rocky subtidal habitats of British Columbia (Bernard 1977; Campbell and Harbo 1991). Sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their traditional food, social and ceremonial fisheries. The commercial red sea urchin fishery began in British Columbia (BC) in the early 1970's and the total landed value for the 2003-2004 season was $7.7 million (Juanita Rogers, pers. comm.), making the harvest of red sea urchins a valuable shellfish fishery in BC.

The commercial red sea urchin fishery history and management were described in Campbell and Harbo (1991), and Campbell et al. (1999a). Currently, several approaches are used in the management of the red sea urchin fishery, including: a minimum commercial harvest size of 90 mm test diameter (TD); area licensing; individual vessel quotas; area quotas; and limited licence entry. Quota calculations are based on estimates of urchin density from field surveys, and estimates of urchin bed areas. Density estimates are therefore essential to the assessment and management of the sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Breen et al. (1976, 1978), Adkins et al. (1981) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a-d; Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-g).

Fishery managers request that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. The Dundas Group area [parts of Pacific Fishery Management (PFM) sub-areas 3-1, 3-2, 4-1, and 4-5] (Figure 1), was selected for survey through discussion between PUHA and DFO. The objective of this paper was to present detailed survey results and to estimate red sea urchin density and biomass for PFM sub-areas 3-1, 3-2, 4-1, and 4-5.

METHODS

Survey Area and Transect Layout

Survey efforts were concentrated in PFM sub-areas 3-1, 3-2, 4-1, and 4-5. Transect locations were selected and plotted on a marine chart prior to the survey to avoid bias in the field.

Transects were systematically placed along the shoreline with a random starting point. The ArcView GIS system was used to measure the shoreline length (SL) of the

survey area, including islands. The position of the first transect was determined randomly, and subsequent transects were then spaced evenly along the shoreline. Areas of unsuitable red sea urchin habitat (eg. sand and mud substrates) were excluded from the survey area. Since variation in urchin density was unlikely to match the spacing of the transects, the systematic sample was treated as a random sample of transects (Jamieson and Schwarz 1998).

SURVEY LOGISTICS

The survey was conducted between August 29 and September 5, 2003. The PUHA provided the "Westport I", a commercial red sea urchin fishing vessel, with a crew of three people consisting of two divers, one of which was a biologist, and the other a commercial red sea urchin harvester, and a boat tender.

DIVE SURVEY METHODS

In the field, locations of transects were determined from geographical references on the shoreline, and GPS. Exposure to wave action/current was recorded, for each transect, as one of nine codes: 0 = extreme shelter, 1 = minimal sea movement, 2 = well sheltered, 3 = occasional current, 4 = moderate exposure, 5 = strong tidal flow, 6 = high tide surge only, 7 = ground swell normal, 8 = high exposure. Leadline transects were laid perpendicular to shore from the boat, with a float attached to the deep end of each transect. Transects were laid out from shallow water to a depth of 15m (not corrected for tide), so transect length was dependent on the slope of the substrate and tide height. A two-diver team surveyed each transect from deep to shallow, one diver measured urchins while the other recorded data. A one meter squared (1 m^2) quadrat was placed on the bottom beside the transect and the test diameter (TD) of each red urchin present was measured, with callipers, to the nearest millimeter. If urchins could not be measured because they were inaccessible or broken/lost they were still counted, therefore the count of urchins in a quadrat may be higher than the number measured. The depth, substrate type, types of algae (and percent cover), shell length of abalone (*Haliotis kamtschatkana*), and TD of green (*S. droebachiensis*) and purple (*S. purpuratus*) sea urchins present in each quadrat were also recorded. The quadrat was then moved 2 m forward along the transect and the process was repeated, so that every second meter of the transect was surveyed. In cases where no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded only every 20 m to minimize dive time. In such cases, skipped quadrats were assigned zero values for urchin counts before data were analysed. Once urchins were encountered, sampling was conducted every 2 m until the intertidal zone or the surface was reached.

DATA ANALYSIS

Habitat

Depth Categories

Gauge depths recorded by divers were corrected to depth below Chart Datum by subtracting tide height from the observed depths. Tide heights from the closest tide station were used to correct depths. The depth (m) for each quadrat was assigned to one of seven depth ranges: 1= <0.0m; 2= 0.0 - <2.5m; 3= 2.5 - <5.0m; 4= 5.0 - <7.5m; 5= 7.5 - <10.0m; 6= 10.0 -<12.5m; and 7= ≥12.5m.

Substrate

The divers record the dominant substrates (up to three) within each quadrat using one of nine generic codes: 1=smooth bedrock; 2=bedrock with crevices; 3=boulders, >30cm; 4=cobble, between 7.5cm and 30cm; 5=gravel, between 2cm and 7.5cm; 6=pea gravel, between 0.25-2cm; 7=sand; 8=shell; and 9=mud. For the analysis, the nine substrate codes were grouped into three main dominant categories: 1=rock (codes 1-5); 2=sand/shell (codes 6-8); and 3=mud (code 9). Each quadrat was assigned a dominant substrate code in order to determine the average percent of each dominant substrate.

Algae

Algal species were assigned to one of four categories based on growth characteristics: canopy (taller than 2m), understorey (30cm to 2m), turf (<30cm), and encrusting. The percent cover of algae in each category, for each quadrat, was calculated as the sum of the individual species' percent cover. Mean percent cover, by growth category, for each depth category was then calculated by averaging the quadrat percent covers over the depth category.

Estimation of Density and Biomass

Density and biomass estimates were calculated from transects that were located inside commercially harvested red sea urchin beds, for transects located outside of the harvested beds, and for all transects combined. Commercially harvested beds were defined as areas where commercial harvesting occurred between 1997 and 2000; therefore, areas defined as outside beds may have had fishing events prior to 1997 and/or after 2000. The process involved in defining the commercially harvested urchin beds was described by Campbell et al. (2001).

Density and biomass were estimated for red urchins in three size groups: a) all sizes, b) small urchins <50 mm TD, and c) urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass were calculated using the equations below.

Density estimates (d_{ts}) in number of red sea urchins per meter squared for each transect (t) and size group (s) were calculated as:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}} \quad (1)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mts} is the number of red urchins measured in size group s on transect t, N_{mt} is the total number of red urchins measured on transect t, and a_t is the surface area of all quadrats surveyed on the transect t. Here a_t is equal to the number of all quadrats surveyed on the transect since each quadrat had a surface area of 1 m^2.

Overall mean density ($\bar{d}_s$) for a PFM sub-area, for urchins of size group s, was estimated as a weighted mean of transect densities:

$$\bar{d}_s = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t} \quad (2)$$

where L_t is the length of transect t (Campbell et al. 1999b).

The standard error ($s_{\bar{d}}$) of estimated mean density was calculated as:

$$s_{\bar{d}} = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \bar{d}_s * L_t)^2}{n * (n-1) * \bar{L}^2}} \quad (3)$$

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled in a surveyed PFM sub-area and mean transect length ($\bar{L}$) was calculated as:

$$\bar{L} = \frac{\sum_t L_t}{n} \quad \text{(Campbell et al. 1999b)} \quad (4)$$

The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of each red urchin measured was calculated using the relationship between urchin weight (W) in grams and test diameter (TD) in millimetres (Campbell et al. 1999b, 2000).

$$W = 0.0012659 * TD^{2.7088} \quad n = 167,\ r^2 = 0.960 \quad (5)$$

Biomass density (b_{ts} in grams per meter squared) of urchins of size group s, on a transect t, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t} \quad (6)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mt} is the total number of red urchins measured on transect t, ΣW_{ts} is the sum of the weights of red urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass ($\bar{b}_s$) per surface area (grams per meter squared) was calculated as a weighted mean of transect biomass:

$$\bar{b}_s = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell et al. 1999b)} \qquad (7)$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density, but d_{ts} and $\bar{d}_s$ were substituted for b_{ts} and $\bar{b}_s$, respectively. The biomass estimate, for each PFM sub-area surveyed, was converted into quota recommendations for management purposes by Campbell et al. (2001).

A Kruskal Wallace Analysis (Systat 10) was used to compare red urchin densities between inside and outside of commercial beds overall and for each PFM sub-area.

Density and biomass estimates were also generated by depth.

Recruitment

Estimates of recruitment (R_T) of red sea urchin populations in BC have generally been expressed as a percentage of the total number of red sea urchins measured that were ≤50 mm TD (Adkins et al. 1981; Breen et al. 1976, 1978; Jamieson et al. 1998b, 1998c, 1998d; Sloan et al. 1987). For comparison purposes, the same method was used here. Recruitment was also calculated as a percentage of the total number of sub-legal red sea urchins (<90 mm TD) that were ≤50 mm TD (R_S). This method may provide a less biased measure of recruitment in areas where a commercial fishery has taken place, since the numbers of sea urchins ≥90 mm TD may be reduced due to the harvest (Tegner and Dayton 1981).

RESULTS

Survey Logistics

In total, 67 transects were surveyed during eight dive days (Table 1, Figure 1). A total of 2460 red sea urchins were measured in 1863 quadrats on the 67 transects. Total transect length surveyed was 3659 m, for an average transect length of 55 m. Thirty (30) transects were located in the commercial red sea urchin beds recorded from 1997 to 2000.

Substrate and Habitat

All transects surveyed were located in areas of high exposure. Of the 1863 quadrats sampled, 57% had rock, 40% had sand/shell, and 3% had mud as the primary substrate. Of the 2465 red sea urchins measured, 82% were observed between 0.0 m and 7.5 m depth.

Encrusting algae were consistently encountered at all depths surveyed; turf and understorey algae showed an increase in abundance with a decrease in depth. Canopy algae were scarce, but were encountered at all depths to 10 m (Table 2).

Size Frequency Distributions

The mean size of all red sea urchins measured was 101.2 mm TD (Table 3, Figure 2). The smallest and largest red urchin measured was 9 mm and 175 mm TD, respectively. By PFM sub-area, mean size ranged from 99.5 mm TD in sub-area 3-1 to 120.2 mm TD in sub-area 3-2. Overall, the mean size of red urchins found inside and outside of commercial bed areas was 102.2 mm and 100.2 mm TD, respectively.

The overall percentage of legal-sized red sea urchins (≥90 mm TD) was 73.3%, whereas the overall percentage of red urchins ≤50 mm TD (R_T) was 5.6%. Of the sublegal urchins, the percentage ≤50 mm TD (R_S) was 20.9%. By PFM sub-area, the percentage of legal-sized red sea urchins ranged from 69.2% (sub-area 3-1) to 92.0% (sub-area 3-2); the percentage of urchin's ≤50 mm TD (R_T) ranged from 1.1% (sub-area 3-2) to 7.1% (sub-area 4-1) (Table 3).

Seventy-five percent (75%) of the red sea urchins sampled inside commercial bed areas (n=1214) were of legal size, as were 72% of the red urchins sampled outside commercial bed areas (n=1246) (Table 3).

Density and Biomass Estimates

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes was 1.32/m^2 and 522.55 g/m^2, respectively, and 0.97/m^2 and 475.28 g/m^2 for legal-sized urchins (Table 4). Although differences in density and biomass between in and out of bed areas were observed for all size groupings, the differences were not significant (Table 5). Overall (PFM sub-areas combined), for transects lying within recorded red sea urchin beds, the estimated mean density of red urchins of all sizes was 1.39/m^2, and was 1.04/m^2 for legal-sized urchins. For transects lying outside of commercial bed areas, the estimated mean density was 1.27/m^2 for red urchins of all sizes, and 0.91/m^2 for legal-sized urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 572.11 g/m^2, and was 528.83 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 478.50 g/m^2 and 427.66 g/m^2, respectively (Table 4).

Overall, the highest mean density and biomass of red sea urchins of any size category was observed at depths between zero and five meters (0-5 m) for both inside and outside of commercial bed areas (Tables 6 and 7), although no statistical tests were performed.

DISCUSSION

Due to the broad nature of this survey, and the small sample of transects surveyed in half of the PFM sub-areas, it is difficult to make any comparisons on a per sub-area basis. For this reason comparisons will be made for the survey as a whole.

The total red sea urchin density observed during this survey (1.32/m^2) was similar to that in Laredo Channel in 2000 (1.09/m^2) (Tzotzos et al. 2003c) and Beaver Pass in 2002 (1.10/m^2) (Atkins et al. 2006b); but was lower than other surveys along the north and central coast of BC, including Banks Island in 1997 (2.23/m^2) (Bureau et al. 2000d), Campania Island in 2004 (3.08/m^2) (Atkins et al. 2006c), and Price Island in 2001 (6.98/m^2) (Tzotzos et al. 2006).

Red sea urchin recruitment in the Dundas Group is low. The density of red urchins ≤50 mm TD (0.07/m^2) is the lowest of all surveys since 2001 with the exception of a 2001 survey near Robson Bight (0.04/m^2) (Atkins et al. 2006d). The percent of red urchins measured that were ≤50 mm TD (R_T) was also very low (5.1%); only two surveys since 2001 were as low or lower: Robson Bight in 2001 (5.0%) (Atkins et al. 2006d) and Becher Bay in 2001 (1.4%) (Tzotzos et al. 2003d). The low recruitment levels observed may be as a result of removing the breeding adults through harvesting. Overall, no significant differences were observed in density when compared between inside and outside of known commercial beds, suggesting that population growth (recruitment) is not being limited through over-fishing. Low recruitment, combined with the corresponding large mean TD (101.2 mm), and high percent of legal-sized red urchins (73.3%) with a low overall density (1.32/m^2) would suggest that environmental effects are limiting population growth. Numerous factors could influence recruitment at any given area including physical and oceanographic influences, predation on larvae and juveniles, and interactions between juveniles and adults (Kalvass 1992; Sloan et al. 1987). High currents and heavy seas may play a major role in keeping local recruitment at a low level.

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Table 1. Summary of transects surveyed during the August 29 - September 5, 2003 red sea urchin (RSU) population survey in the Dundas Group. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management. Depths have been corrected to chart datum. Check marks (✓) indicate transect lying within a known commercial RSU harvest area.

Transect	PFM Sub-area	Latitude	Longitude	Depth (m)		Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum	Start	End							
6	3-1	54 36.550	130 56.337	0.94	14.63	09:45	10:29	44	61	31	108	3.48	811.76	
7	3-1	54 37.938	130 54.387	1.83	12.53	11:20	11:55	35	61	31	44	1.42	492.31	
8	3-1	54 37.903	130 53.847	2.16	16.58	12:02	12:28	26	63	32	69	2.16	897.91	
9	3-1	54 37.569	130 51.015	-2.32	6.37	14:49	15:26	37	53	27	26	0.96	427.70	
10	3-1	54 37.486	130 47.211	-3.32	8.84	17:13	17:45	32	53	27	64	2.37	962.28	
11	3-2	54 37.253	130 46.006	-0.88	2.96	09:07	09:24	17	63	32	0	0.00	0.00	✓
12	3-2	54 36.571	130 45.391	3.63	9.24	09:45	10:17	32	59	30	23	0.77	522.17	✓
13	3-2	54 35.516	130 45.224	-0.94	10.52	12:13	12:48	35	57	29	33	1.14	638.71	✓
14	4-5	54 33.843	130 45.792	-0.76	11.19	11:05	11:35	30	59	30	38	1.27	538.78	✓
15	4-1	54 32.494	130 47.962	-0.79	12.71	13:47	14:09	22	59	30	3	0.10	61.18	✓
16	4-1	54 31.627	130 49.630	-2.19	4.79	14:34	15:10	36	59	30	44	1.47	742.22	✓
17	4-1	54 30.939	130 50.937	-1.71	6.92	15:34	15:42	8	59	30	0	0.00	0.00	✓
18	4-1	54 30.490	130 51.157	0.88	12.01	16:02	16:28	26	59	30	63	2.10	670.01	✓
19	4-1	54 29.613	130 52.602	-3.26	4.05	16:53	17:25	32	59	30	96	3.20	1130.70	✓
20	4-1	54 29.112	130 54.569	-3.66	6.89	10:06	10:30	24	59	30	28	0.93	437.08	
21	4-1	54 28.437	130 55.313	-2.38	6.95	09:09	09:50	41	59	30	43	1.43	654.27	
22	4-1	54 27.706	130 56.820	0.76	12.71	09:24	09:57	33	59	30	54	1.80	656.21	✓
23	4-1	54 27.492	130 56.956	0.88	10.36	10:19	10:50	31	59	30	59	1.97	887.32	✓
24	4-1	54 27.344	130 57.442	2.41	9.02	11:13	11:42	29	59	30	29	0.97	317.80	
25	4-1	54 27.042	130 57.945	0.21	5.85	12:04	12:36	32	59	30	61	2.03	1062.23	✓
26	3-1	54 28.132	130 59.201	1.43	7.04	14:28	15:26	58	55	28	161	5.75	2523.75	✓
27	3-1	54 28.506	130 58.151	0.64	2.44	13:58	14:20	22	57	29	0	0.00	0.00	✓
28	4-1	54 31.254	130 49.091	0.76	11.03	12:12	12:45	33	59	30	56	1.87	715.73	✓
29	4-1	54 30.631	130 49.126	0.82	7.74	13:15	14:00	45	59	30	5	0.17	101.55	✓
30	4-1	54 29.861	130 50.644	-3.02	5.85	14:47	15:36	49	59	30	35	1.17	361.08	✓
31	4-1	54 29.598	130 50.781	-3.14	8.50	15:52	16:30	38	59	30	41	1.37	696.45	✓
32	4-1	54 29.135	130 50.765	-5.52	3.41	17:53	18:18	25	47	24	0	0.00	0.00	✓
33	4-1	54 29.188	130 50.092	-3.81	3.47	16:55	17:26	31	59	30	16	0.53	462.77	
34	4-1	54 27.950	130 51.449	-0.30	11.83	10:52	11:24	32	61	31	46	1.48	657.25	✓
35	4-1	54 26.145	130 53.287	-1.62	14.51	13:50	14:08	18	59	30	33	1.10	364.75	
36	4-1	54 25.905	130 53.547	-1.80	6.46	11:50	12:30	40	59	30	83	2.77	982.67	
37	4-1	54 27.150	130 48.881	-4.60	-0.37	17:27	17:50	23	19	10	0	0.00	0.00	✓

Continued next page

Table 1. continued

Transect	PFM Sub-area	Latitude	Longitude	Depth (m)		Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum	Start	End							
38	4-1	54 26.833	130 49.965	-2.65	3.93	16:50	17:12	22	59	30	57	1.90	854.78	✓
39	4-1	54 26.304	130 51.012	-1.89	11.40	15:58	16:25	27	59	30	57	1.90	734.15	
40	4-1	54 25.955	130 52.253	-1.04	12.10	14:23	14:51	28	59	30	75	2.50	1054.08	✓
41	4-1	54 26.364	130 52.027	1.16	11.73	16:24	16:45	21	61	31	33	1.06	365.95	✓
42	4-1	54 26.099	130 52.208	-2.29	14.69	11:13	11:30	17	23	12	21	1.75	710.51	
43	4-1	54 27.636	130 51.019	-0.40	11.28	11:43	12:06	23	61	31	15	0.48	216.31	
44	4-1	54 28.988	130 49.366	-0.37	7.86	09:12	09:55	43	61	31	42	1.35	486.66	✓
45	4-5	54 30.836	130 45.165	-0.79	2.32	09:05	09:37	32	59	30	44	1.47	681.88	✓
46	4-5	54 28.493	130 46.563	-2.74	13.05	09:10	10:19	69	59	30	0	0.00	0.00	
47	4-5	54 28.129	130 44.781	-1.01	15.88	10:47	11:11	24	35	18	9	0.50	127.80	
48	4-5	54 24.915	130 41.392	0.94	11.83	14:30	14:48	18	57	29	16	0.55	309.96	
49	4-5	54 23.734	130 42.327	-2.99	0.82	16:07	16:19	12	59	30	0	0.00	0.00	
55	4-1	54 23.671	130 48.333	-1.22	0.88	15:05	15:14	9	59	30	0	0.00	0.00	
56	4-1	54 24.047	130 48.500	-1.65	6.86	14:35	14:47	12	59	30	0	0.00	0.00	✓
57	4-1	54 24.381	130 48.539	-1.77	12.44	14:00	14:21	21	59	30	48	1.60	583.75	✓
58	4-1	54 24.657	130 48.597	-2.68	7.19	11:48	12:19	31	59	30	68	2.27	845.08	
59	4-1	54 25.086	130 50.602	-1.19	8.20	10:54	11:21	27	61	31	70	2.26	508.44	✓
60	4-1	54 26.655	130 49.391	-2.38	9.63	17:28	17:44	16	59	30	27	0.90	321.25	✓
62	3-1	54 32.403	130 58.607	1.25	8.53	17:22	18:01	39	59	30	145	4.83	1856.69	
64	3-1	54 36.704	130 51.240	-1.71	13.62	13:49	14:28	39	51	26	12	0.46	260.77	
65	3-1	54 38.191	130 49.236	-4.11	11.06	16:14	16:49	35	35	18	117	6.50	1812.37	
66	3-1	54 36.848	130 48.748	-2.74	12.71	18:11	18:36	25	27	14	58	4.14	1711.44	
67	3-2	54 36.187	130 45.098	0.67	16.86	10:35	11:02	27	29	15	31	2.07	1108.12	
68	4-5	54 33.053	130 46.575	-2.56	10.61	10:11	10:34	23	43	22	23	1.05	496.61	
69	3-1	54 29.298	130 58.494	1.28	12.16	16:20	16:36	16	21	11	28	2.55	681.77	
71	4-1	54 23.555	130 48.162	-1.49	1.55	15:24	15:30	6	59	30	0	0.00	0.00	
72	4-1	54 25.147	130 47.990	-3.75	10.00	10:07	10:29	22	39	20	0	0.00	0.00	
73	4-1	54 25.788	130 49.130	-3.99	14.05	09:29	09:48	19	47	24	0	0.00	0.00	
74	4-1	54 26.004	130 51.687	-0.34	5.91	15:08	15:37	29	53	27	80	2.96	1024.51	
75	4-1	54 27.243	130 51.479	-0.30	11.22	15:24	15:54	30	59	30	17	0.57	229.19	
76	4-1	54 28.383	130 50.276	-0.24	6.34	10:14	10:33	19	65	33	0	0.00	0.00	
77	4-5	54 28.115	130 45.651	-0.06	9.51	09:57	10:17	20	59	30	0	0.00	0.00	
78	4-5	54 27.084	130 43.792	-0.46	12.89	11:37	11:55	18	59	30	9	0.30	85.93	
79	4-5	54 26.093	130 44.289	-3.11	-0.58	17:01	17:19	18	59	30	0	0.00	0.00	
80	4-5	54 23.437	130 42.101	-2.07	5.36	15:13	15:40	27	57	29	2	0.07	43.74	

Table 2. Mean number of red sea urchins (RSU), mean substrate category, and percent cover of algae for each depth range surveyed during the 2001 survey conducted in the Dundas Group. Depths have been corrected to chart datum. Substrate categories: 1=rock; 2=sand/shell; 3=mud. Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, crustose layer on rocks.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
PFM sub-area 3-1								
<0.0 m	72	2.6	28	1.00	0	42.1	3.2	57.3
0.0 - <2.5 m	219	3.3	67	1.10	6.8	52.9	4.5	32.5
2.5 - <5.0 m	274	4.7	58	1.14	1.4	12.3	0.5	57.4
5.0 - <7.5 m	159	3.2	50	1.10	0	7.6	<0.1	57.5
7.5 - <10.0 m	75	1.8	41	1.15	0	4.2	3.5	38.1
10.0 - <12.5 m	28	1.0	28	1.57	0	4.3	2.9	33.8
≥12.5 m	5	0.2	32	1.80	0	0	0	10.6
PFM sub-area 3-2								
<0.0 m	0	0.0	6	1.00	0.8	61.7	41.7	63.3
0.0 - <2.5 m	9	0.5	17	1.00	22.9	55.3	27.1	81.8
2.5 - <5.0 m	31	0.9	33	1.70	2.1	67.7	1.8	26.5
5.0 - <7.5 m	22	1.0	21	1.57	0.1	8.0	1.7	40.3
7.5 - <10.0 m	16	0.8	20	1.70	0	9.5	0	25.9
10.0 - <12.5 m	8	1.3	6	1.83	0	0	0.8	21.7
≥12.5 m	1	0.3	3	1.00	0	0	5	100
PFM sub-area 4-1								
<0.0 m	22	0.1	171	1.00	1.1	24.4	21.8	63.1
0.0 - <2.5 m	535	2.1	260	1.41	7.0	26.3	17.4	41.8
2.5 - <5.0 m	468	2.2	214	1.32	0.5	5.1	8.5	39.8
5.0 - <7.5 m	200	0.9	211	1.77	1.0	18.0	7.0	22.3
7.5 - <10.0 m	149	1.0	149	1.51	0.1	8.1	4.2	27.6
10.0 - <12.5 m	31	0.3	106	1.92	0	1.6	0.2	7.2
≥12.5 m	0	0.0	34	1.91	0	0	0	5.0

Continued next page

Table 2. continued.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
PFM sub-area 4-5								
<0.0 m	0	0.0	70	1.06	0.6	25.4	46.4	30.2
0.0 - <2.5 m	47	0.7	66	1.55	2.1	36.1	7.0	38.4
2.5 - <5.0 m	20	0.7	30	1.20	0	13.5	14.0	66.2
5.0 - <7.5 m	32	0.9	36	1.64	0	9.0	3.3	39.2
7.5 - <10.0 m	36	0.8	45	1.87	0	12.1	2.2	18.0
10.0 - <12.5 m	6	0.3	24	1.88	0	0.8	2.5	7.9
≥12.5 m	0	0.0	37	2.35	0	0	0	0
PFM sub-areas Combined								
<0.0 m	94	0.3	275	1.01	0.8	27.3	26.6	54.1
0.0 - <2.5 m	810	2.0	410	1.41	6.9	33.4	14.0	41.4
2.5 - <5.0 m	793	2.4	335	1.31	0.8	13.3	7.0	43.9
5.0 - <7.5 m	413	1.3	318	1.64	0.7	14.7	5.1	30.9
7.5 - <10.0 m	276	1.1	255	1.53	0.1	8.3	3.4	27.5
10.0 - <12.5 m	73	0.4	164	1.85	0	1.9	1.0	12.4
≥12.5 m	6	0.1	106	2.03	0	0	0.1	7.6

Table 3. Number and mean size of red sea urchins measured and percent of urchins ≤50 mm TD and ≥90 mm TD for each Pacific Fishery Management (PFM) sub-area surveyed during the 2003 population survey in the Dundas Group. R_T = percent of all red urchins that were ≤50 mm TD. R_S = percent of sublegal urchins that were ≤50 mm TD.

PFM	Transects	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegal
Sub-area	Used	Mean	Minimum	Maximum	Total	≤50 mm TD	≥90 mm TD	≤50 mm (R_T)	≥90 mm	≤50 mm (R_S)
3-1	Within Beds	106.7	18	165	161	3	126	1.9	78.3	8.6
	Outside Beds	97.7	11	152	671	27	450	4.0	67.1	12.2
	All	99.5	11	165	832	30	576	3.6	69.2	11.7
3-2	Within Beds	121.4	30	162	56	1	50	1.8	89.3	16.7
	Outside Beds	118.1	68	142	31	0	30	0.0	96.8	0.0
	All	120.2	30	162	87	1	80	1.1	92.0	14.3
4-1	Within Beds	99.8	9	167	915	71	666	7.8	72.8	28.5
	Outside Beds	101.8	9	175	485	29	372	6.0	76.7	25.7
	All	100.5	9	175	1400	100	1038	7.1	74.1	27.6
4-5	Within Beds	107.1	34	159	82	2	65	2.4	79.3	11.8
	Outside Beds	105.1	16	159	59	4	45	6.8	76.3	28.6
	All	106.3	16	159	141	6	110	4.3	78.0	19.4
Survey	Within Beds	102.2	9	167	1214	77	907	6.3	74.7	25.1
Total	Outside Beds	100.2	9	175	1246	60	897	4.8	72.0	17.2
	All	101.2	9	175	2460	137	1804	5.6	73.3	20.9

Table 4. Mean density and biomass estimates of red sea urchins by size (test diameter, TD), within and outside of commercial beds, by Pacific Fishery Management sub-area, for the 2003 survey in the Dundas Group. Estimates are for transects within red sea urchin beds recorded between 1997 and 2000, for transects outside the beds, and for all transects combined. Values in brackets are ± S.E..

PFM Sub-areas	Transects Surveyed	Number Of Transects	Sum of Transect Lengths (m)	Mean Density (/m^2) by TD			Mean Biomass (g/m^2) by TD		
				≤50 mm	≥90 mm	All Sizes	≤50 mm	≥90 mm	All Sizes
3-1	Within Beds	2	112	0.05	2.21	2.82	0.41	1137.93	1239.34
	Outside Beds	10	484	0.11 (0.04)	1.82 (0.37)	2.71 (0.56)	2.46 (0.86)	805.32 (163.19)	943.37 (183.23)
	All	12	596	0.10 (0.04)	1.89 (0.44)	2.73 (0.60)	2.08 (0.74)	867.82 (211.68)	998.98 (232.00)
3-2	Within Beds	3	179	0.01	0.55	0.62	0.14	368.96	375.50
	Outside Beds	1	29	0.00	2.00	2.07	0.00	1100.42	1108.12
	All	4	208	0.01	0.75	0.82	0.12	470.95	477.64
4-1	Within Beds	23	1313	0.11 (0.03)	1.00 (0.14)	1.37 (0.18)	1.04 (0.30)	494.26 (68.96)	538.56 (73.88)
	Outside Beds	17	937	0.06 (0.04)	0.79 (0.18)	1.0[illegible] (0.24)	0.84 (0.51)	382.51 (79.24)	413.10 (86.48)
	All	40	2250	0.09 (0.02)	0.91 (0.11)	1.23 (0.15)	0.96 (0.27)	447.72 (52.27)	486.31 (56.50)
4-5	Within Beds	2	118	0.03	1.08	1.37	0.69	577.91	610.33
	Outside Beds	9	487	0.02 (0.01)	0.18 (0.09)	0.24 (0.11)	0.26 (0.17)	99.14 (50.76)	104.84 (52.79)
	All	11	605	0.02 (0.01)	0.36 (0.14)	0.46 (0.17)	0.34 (0.15)	192.52 (75.44)	203.43 (79.41)
Survey Total	Within Beds	30	1722	0.09 (0.03)	1.04 (0.16)	1.39 (0.21)	0.88 (0.24)	528.83 (82.82)	572.11 (89.56)
	Outside Beds	37	1937	0.06 (0.02)	0.91 (0.16)	1.27 (0.23)	1.09 (0.35)	427.66 (70.46)	478.50 (79.63)
	All	67	3659	0.07 (0.02)	0.97 (0.11)	1.32 (0.16)	0.99 (0.21)	475.28 (54.04)	522.55 (59.59)

Table 5. Kruskal-Wallace test results for comparing mean densities of red sea urchins by size groups between inside and outside commercial bed areas by PFM sub-area for the 2004 survey in the Dundas Group.

PFM Sub-area	P-values		
	≤50 mm	≥90 mm	All Sizes
3-1	0.451	1.000	0.830
3-2	0.564	0.180	0.180
4-1	0.142	0.322	0.283
4-5	0.299	**0.030**	**0.030**
PFM sub-areas combined	0.357	0.573	0.662

Table 6. Mean density estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2002 survey in the Dundas Group. Values in brackets are ± S.E.

Depth Range (m)	Transect Count	Mean Density (number/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 3-1										
<0.0 m	5	0.00	0.02 (0.02)	0.02 (0.02)	0.00	0.91 (0.68)	0.91 (0.68)	0.00	1.49 (1.22)	1.49 (1.22)
0.0 – <2.5 m	12	0.00	0.25 (0.06)	0.20 (0.06)	0.00	6.14 (1.65)	4.99 (1.53)	0.00	8.34 (1.93)	6.77 (1.87)
2.5 – <5.0 m	11	0.19	0.17 (0.08)	0.18 (0.07)	7.83	2.68 (0.71)	3.20 (0.81)	10.00	3.93 (0.88)	4.55 (0.99)
5.0 – <7.5 m	10	0.08	0.09 (0.03)	0.09 (0.03)	3.34	1.81 (0.32)	1.97 (0.33)	4.26	2.61 (0.50)	2.79 (0.48)
7.5 – <10.0 m	9	0.00	0.10 (0.04)	0.10 (0.04)	0.00	1.32 (0.30)	1.32 (0.30)	0.00	2.00 (0.50)	2.00 (0.50)
10.0 – <12.5 m	6	0.00	0.10 (0.08)	0.10 (0.08)	0.00	0.53 (0.22)	0.53 (0.22)	0.00	1.16 (0.62)	1.16 (0.62)
≥12.5 m	5	0.00	0.02 (0.01)	0.02 (0.01)	0.00	0.09 (0.06)	0.09 (0.06)	0.00	0.16 (0.10)	0.16 (0.10)
PFM sub-area 3-2										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	3	0.00	0.00	0.00	0.00	2.18	0.42	0.00	2.25	0.44
2.5 – <5.0 m	4	0.03	0.00	0.02	1.44	4.19	1.83	1.61	4.33	1.99
5.0 – <7.5 m	3	0.02	0.00	0.02	1.16	0.00	0.92	1.29	0.00	1.04
7.5 – <10.0 m	3	0.01	0.00	0.00	1.06	0.97	1.04	1.20	1.00	1.16
10.0 – <12.5 m	2	0.00	0.00	0.00	0.35	5.81	2.19	0.40	6.00	2.29
≥12.5 m	1	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.33	0.33
PFM sub-area 4-1										
<0.0 m	32	0.03 (0.02)	0.01 (0.01)	0.02 (0.01)	0.17 (0.14)	0.40 (0.23)	0.29 (0.13)	0.24 (0.16)	0.45 (0.25)	0.34 (0.15)
0.0 – <2.5 m	39	0.18 (0.09)	0.08 (0.05)	0.14 (0.06)	1.73 (0.39)	1.52 (0.41)	1.64 (0.28)	2.41 (0.55)	1.96 (0.56)	2.22 (0.39)
2.5 – <5.0 m	35	0.16 (0.04)	0.06 (0.02)	0.12 (0.03)	2.12 (0.67)	1.61 (0.34)	1.91 (0.41)	2.82 (0.88)	1.96 (0.40)	2.46 (0.54)
5.0 – <7.5 m	30	0.14 (0.04)	0.06 (0.04)	0.11 (0.03)	1.23 (0.29)	1.02 (0.24)	1.14 (0.19)	1.70 (0.38)	1.33 (0.31)	1.54 (0.25)
7.5 – <10.0 m	18	0.09 (0.04)	0.02 (0.01)	0.07 (0.03)	0.89 (0.29)	0.41 (0.20)	0.73 (0.20)	1.19 (0.39)	0.51 (0.24)	0.96 (0.27)
10.0 – <12.5 m	12	0.06 (0.05)	0.01	0.05 (0.03)	0.43 (0.23)	0.43	0.43 (0.19)	0.61 (0.34)	0.51	0.58 (0.27)
≥12.5 m	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Table 6. continued.

Depth Range (m)	Transect Count	Mean Density (number/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 4-5										
<0.0 m	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	10	0.03	0.00	0.01 (0.01)	0.92	0.15 (0.12)	0.31 (0.21)	1.22	0.16 (0.13)	0.39 (0.27)
2.5 – <5.0 m	8	0.04	0.11 (0.10)	0.10 (0.09)	1.26	0.46 (0.23)	0.57 (0.23)	1.50	0.77 (0.45)	0.87 (0.40)
5.0 – <7.5 m	7	0.04	0.07 (0.06)	0.07 (0.05)	1.12	0.81 (0.36)	0.86 (0.32)	1.33	1.05 (0.54)	1.10 (0.45)
7.5 – <10.0 m	6	0.04	0.03 (0.03)	0.03 (0.02)	1.36	0.53 (0.55)	0.68 (0.47)	1.62	0.64 (0.66)	0.82 (0.56)
10.0 – <12.5 m	5	0.04	0.00	0.01 (0.01)	1.26	0.00	0.29 (0.28)	1.50	0.00	0.35 (0.34)
≥12.5 m	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All PFM sub-areas combined										
<0.0 m	49	0.02 (0.02)	0.01 (0.01)	0.01 (0.01)	0.14 (0.11)	0.36 (0.16)	0.27 (0.10)	0.19 (0.13)	0.47 (0.22)	0.35 (0.14)
0.0– <2.5 m	64	0.14 (0.07)	0.11 (0.03)	0.12 (0.04)	1.43 (0.33)	2.41 (0.60)	1.95 (0.36)	1.98 (0.46)	3.20 (0.76)	2.63 (0.46)
2.5 – <5.0 m	58	0.14 (0.03)	0.10 (0.03)	0.12 (0.02)	2.21 (0.58)	1.71 (0.30)	1.94 (0.31)	2.89 (0.76)	2.30 (0.39)	2.57 (0.41)
5.0 – <7.5 m	50	0.12 (0.04)	0.07 (0.02)	0.09 (0.02)	1.32 (0.25)	1.19 (0.18)	1.25 (0.15)	1.76 (0.33)	1.63 (0.26)	1.69 (0.20)
7.5 – <10.0 m	36	0.08 (0.03)	0.05 (0.02)	0.06 (0.02)	0.95 (0.24)	0.82 (0.20)	0.88 (0.15)	1.22 (0.32)	1.16 (0.30)	1.19 (0.21)
10.0 – <12.5 m	25	0.05 (0.04)	0.04 (0.03)	0.05 (0.02)	0.51 (0.20)	0.57 (0.28)	0.54 (0.17)	0.68 (0.28)	0.84 (0.38)	0.77 (0.24)
≥12.5 m	14	0.00	0.01 (0.00)	0.01 (0.00)	0.00	0.06 (0.03)	0.05 (0.03)	0.00	0.09 (0.05)	0.07 (0.04)

Table 7. Biomass estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2002 population survey in the Dundas Group. Values in brackets are ± S.E.

Depth Range (m)	Transect Count	Mean Biomass (g/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 3-1										
<0.0 m	5	0.00	0.39 (0.41)	0.39 (0.41)	0.00	370.63 (276.15)	370.63 (276.15)	0.00	464.72 (358.14)	464.72 (358.14)
0.0 – <2.5 m	12	0.00	5.17 (1.84)	4.20 (1.61)	0.00	2719.73 (749.43)	2208.64 (692.12)	0.00	3065.71 (789.98)	2489.61 (741.08)
2.5 – <5.0 m	11	1.47	3.51 (1.58)	3.30 (1.43)	4029.98	1177.53 (317.50)	1468.60 (400.00)	4389.12	1370.28 (326.79)	1678.32 (417.75)
5.0 – <7.5 m	10	0.63	2.06 (0.66)	1.90 (0.61)	1718.04	805.25 (135.29)	902.17 (154.91)	1871.15	929.96 (153.97)	1029.89 (170.29)
7.5 – <10.0 m	9	0.00	2.41 (0.94)	2.41 (0.94)	0.00	592.66 (138.32)	592.66 (138.32)	0.00	696.42 (156.35)	696.42 (156.35)
10.0 – <12.5 m	6	0.00	1.75 (1.42)	1.75 (1.42)	0.00	210.95 (79.81)	210.95 (79.81)	0.00	306.84 (138.53)	306.84 (138.53)
≥12.5 m	5	0.00	0.43 (0.26)	0.43 (0.26)	0.00	49.16 (35.56)	49.16 (35.56)	0.00	58.14 (37.33)	58.14 (37.33)
PFM sub-area 3-2										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	3	0.00	0.00	0.00	0.00	1198.03	233.17	0.00	1206.42	234.81
2.5 – <5.0 m	4	0.36	0.00	0.31	968.01	2307.33	1154.74	985.20	2323.47	1171.78
5.0 – <7.5 m	3	0.28	0.00	0.22	773.83	0.00	619.06	787.71	0.00	630.17
7.5 – <10.0 m	3	0.06	0.00	0.05	672.04	532.46	644.12	686.72	536.19	656.61
10.0 – <12.5 m	2	0.00	0.00	0.00	219.41	3194.76	1222.73	224.52	3217.12	1233.65
≥12.5 m	1	0.00	0.00	0.00	0.00	177.49	177.49	0.00	178.73	178.73

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Table 7. continued.

Depth Range (m)	Transect Count	Mean Biomass (g/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 4-1										
<0.0 m	32	0.22 (0.13)	0.13 (0.13)	0.17 (0.09)	70.42 (52.75)	219.68 (142.95)	144.21 (75.65)	76.12 (55.34)	226.55 (144.18)	150.49 (76.67)
0.0– <2.5 m	39	1.34 (0.51)	1.00 (0.67)	1.20 (0.41)	883.19 (210.09)	763.60 (200.54)	832.96 (146.63)	963.82 (229.10)	825.02 (217.45)	905.53 (159.66)
2.5 – <5.0 m	35	1.71 (0.52)	0.68 (0.27)	1.28 (0.33)	986.97 (283.76)	817.10 (176.04)	917.24 (180.50)	1082.61 (320.05)	868.93 (182.59)	994.89 (201.32)
5.0 – <7.5 m	30	1.31 (0.51)	0.84 (0.53)	1.10 (0.36)	647.84 (161.44)	460.41 (106.37)	564.64 (101.48)	702.99 (171.81)	504.28 (115.75)	614.78 (108.51)
7.5 – <10.0 m	18	1.34 (0.71)	0.21 (0.13)	0.95 (0.48)	428.08 (126.36)	174.55 (86.74)	340.61 (89.97)	463.06 (137.05)	186.84 (91.06)	367.76 (97.32)
10.0 – <12.5 m	12	0.91 (0.71)	0.15	0.69 (0.50)	195.78 (102.20)	187.99	193.46 (85.29)	215.33 (113.32)	197.50	210.02 (92.99)
≥12.5 m	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PFM sub-area 4-5										
<0.0 m	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	10	0.49	0.00	0.11 (0.11)	535.91	85.18 (72.89)	182.59 (121.20)	568.23	86.75 (73.83)	190.81 (127.57)
2.5 – <5.0 m	8	0.94	1.98 (1.51)	1.83 (1.29)	607.18	234.70 (113.95)	286.04 (111.00)	638.03	259.49 (128.67)	311.67 (122.84)
5.0 – <7.5 m	7	0.84	2.14 (2.06)	1.93 (1.72)	539.72	400.40 (182.20)	422.67 (152.29)	567.14	418.12 (189.72)	441.94 (158.67)
7.5 – <10.0 m	6	1.02	0.06 (0.07)	0.24 (0.19)	653.86	286.31 (298.17)	355.82 (248.81)	687.11	302.76 (315.29)	375.44 (262.85)
10.0 – <12.5 m	5	0.94	0.00	0.22 (0.21)	607.18	0.00	141.60 (136.29)	638.03	0.00	148.79 (143.21)
≥12.5 m	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Table 7. continued.

Depth Range (m)	Transect Count	Mean Biomass (g/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
All PFM sub-areas combined										
<0.0 m	49	0.17 (0.10)	0.13 (0.09)	0.15 (0.07)	55.67 (42.00)	179.47 (90.63)	126.66 (55.11)	60.17 (44.09)	196.91 (96.34)	138.58 (58.51)
0.0 – <2.5 m	64	1.09 (0.41)	1.83 (0.66)	1.49 (0.40)	733.63 (177.31)	1119.83 (270.32)	939.56 (166.61)	799.41 (193.30)	1240.13 (294.12)	1034.41 (181.50)
2.5 – <5.0 m	58	1.50 (0.42)	1.75 (0.59)	1.64 (0.37)	1083.34 (259.35)	818.72 (141.18)	941.35 (141.65)	1176.68 (289.64)	904.18 (150.18)	1030.46 (155.96)
5.0 – <7.5 m	50	1.15 (0.42)	1.44 (0.51)	1.32 (0.34)	704.61 (138.95)	542.17 (78.91)	612.14 (74.84)	758.88 (148.34)	603.99 (88.05)	670.71 (81.02)
7.5 – <10.0 m	36	1.14 (0.57)	1.07 (0.46)	1.10 (0.35)	478.23 (115.51)	381.41 (97.80)	423.97 (74.12)	510.24 (122.98)	431.72 (108.77)	466.24 (80.60)
10.0 – <12.5 m	25	0.83 (0.57)	0.70 (0.57)	0.76 (0.40)	239.06 (90.81)	271.11 (146.76)	256.21 (87.46)	258.34 (99.27)	310.93 (154.32)	286.47 (92.81)
≥12.5 m	14	0.00	0.20 (0.13)	0.16 (0.11)	0.00	31.49 (18.71)	26.12 (15.74)	0.00	35.67 (19.87)	29.59 (16.79)

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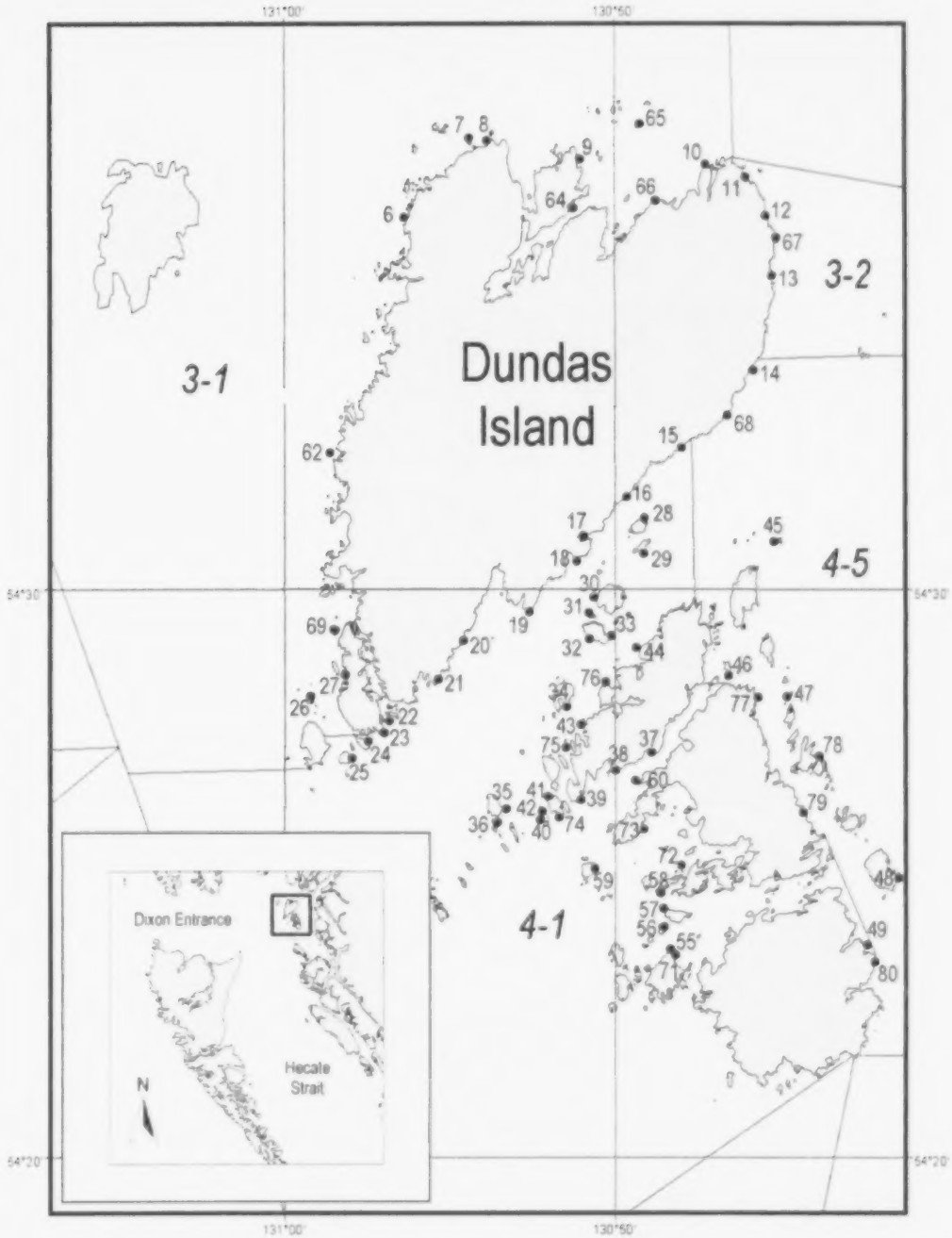

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted off Dundas Island, 2003. Hyphenated numbers indicate Pacific Fishery Management sub-areas, and smaller numbers identify transect locations. Inset figure denotes survey location.

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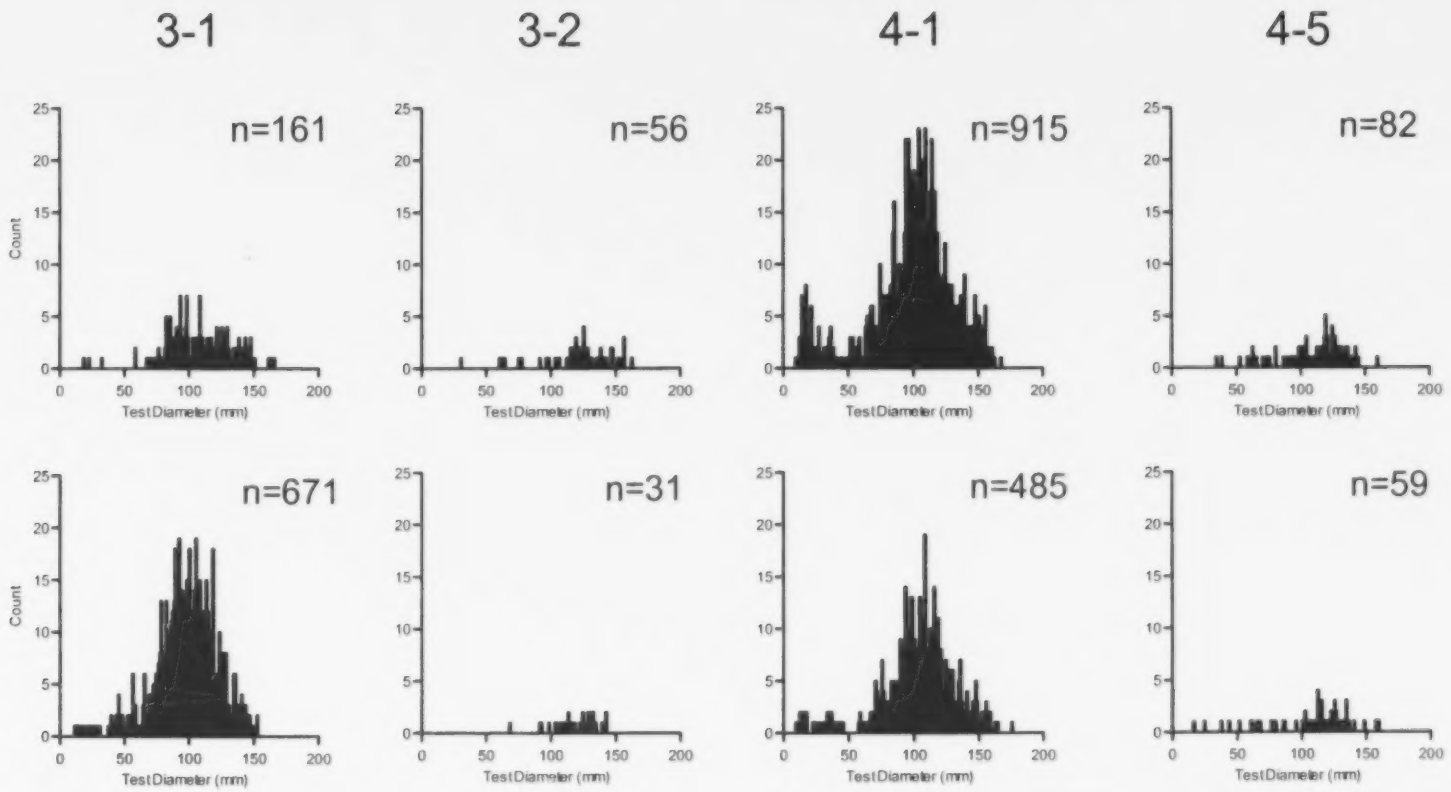

Figure 2. Size frequency distribution of red sea urchins measured inside (top row) and outside (bottom row) of commercial bed areas on all transects surveyed in the Dundas Group, 2003. Pacific Fisheries Management sub-areas area indicated above the figures. n= number of red sea urchins measured for test diameter.